

## **CLAIMS**

What is Claimed is:

1. A method of designing roller-cone drill bits, comprising the actions of:
  - a) simulating operation of a drill bit having multiple design parameters through the formation to be drilled;
  - b) adjusting said multiple bit design parameters by reference to a multi-objective optimization which combines objectives related to maximizing rock removal of subelements, objectives related to equalization of rock removal among groups of said subelements, and also objectives related to minimization of one or more shock loading components; and
  - c) after one or more iterations of said steps a) and b), outputting the results of said step b).
2. The method of Claim 1, wherein said objectives related to maximizing rock removal consist of rate of penetration.
3. The method of Claim 1, wherein said objectives related to minimization of one or more shock loading components consist of balancing the average the bit-axial force components.

4. The method of Claim 1, wherein said objectives related to minimization of one or more shock loading components consist of minimizing the bit net lateral force due to tooth interactions with the bottom of the formation to be drilled.
5. The method of Claim 1, wherein said objectives related to minimization of one or more shock loading components consist of minimizing the distance between teeth surfaces.
6. The method of Claim 1, wherein said objectives related to minimization of one or more shock loading components consist of equalizing the width of the uncut formation rings.
7. A roller cone bit designed by the method of Claim 1.
8. A method of drilling using bits designed by the method of Claim 1.
9. A method of designing roller-cone drill bits, comprising the actions of:
  - adjusting multiple bit design parameters by reference to a multi-objective optimization which combines
    - objectives related to maximizing rock removal of subelements,
    - objectives related to equalization of rock removal among groups of said subelements, and also
    - objectives related to minimization of one or more shock loading components.

10. The method of Claim 9, wherein said objectives related to maximizing rock removal consist of rate of penetration.
11. The method of Claim 9, wherein said objectives related to minimization of one or more shock loading components consist of balancing the average the bit-axial force components.
12. The method of Claim 9, wherein said objectives related to minimization of one or more shock loading components consist of minimizing the bit net lateral force due to tooth interactions with the bottom of the formation to be drilled.
13. The method of Claim 9, wherein said objectives related to minimization of one or more shock loading components consist of minimizing the distance between teeth surfaces.
14. The method of Claim 9, wherein said objectives related to minimization of one or more shock loading components consist of equalizing the width of the uncut formation rings.
15. A roller cone bit designed by the method of Claim 9.
16. A method of drilling using bits designed by the method of Claim 9.

17. A method of designing roller-cone drill bits, comprising the actions of:

- a) simulating operation of a drill bit having multiple design parameters through the formation to be drilled;
- b) adjusting multiple bit design parameters by reference to a multi-objective optimization which combines objectives related to maximizing rock removal of subelements, objectives related to equalization of rock removal among groups of said subelements, and also anti-tracking objectives; and
- c) after one or more iterations of said steps a) and b), outputting the results of said step b).

18. The method of Claim 17, wherein said objectives related to maximizing rock removal consist of rate of penetration.

19. The method of Claim 17, wherein said objectives related to anti-tracking consist of minimizing the width of the uncut formation rings.

20. The method of Claim 17, wherein said objectives related to equalization of rock removal among groups of said subelements consist of balancing the average the bit-axial force components.

21. The method of Claim 17, wherein said objectives related to equalization of rock removal among groups of said subelements consist of minimizing the bit net lateral force due to tooth interactions with the bottom of the formation to be drilled.
22. The method of Claim 17, wherein said objectives related to equalization of rock removal among groups of said subelements consist of equalizing the width of the uncut formation rings.
23. A roller cone bit designed by the method of Claim 17.
24. A method of drilling using bits designed by the method of Claim 17.
25. A method of designing roller-cone drill bits, comprising the actions of:

adjusting multiple bit design parameters by reference to a multi-objective optimization which combines

objectives related to maximizing rock removal of

subelements,

objectives related to equalization of rock removal among

groups of said subelements, and also

anti-tracking objectives.
26. The method of Claim 25, wherein said objectives related to maximizing rock removal consist of rate of penetration.

27. The method of Claim 25, wherein said objectives related to anti-tracking consist of minimizing the width of the uncut formation rings.
28. The method of Claim 25, wherein said objectives related equalization of rock removal among groups of said subelements consist of balancing the average the bit-axial force components.
29. The method of Claim 25, wherein said objectives related to equalization of rock removal among groups of said subelements consist of minimizing the bit net lateral force due to tooth interactions with the bottom of the formation to be drilled.
30. The method of Claim 25, wherein said objectives related to equalization of rock removal among groups of said subelements consist of equalizing the width of the uncut formation rings.
31. A roller cone bit designed by the method of Claim 25.
32. A method of drilling using bits designed by the method of Claim 25.

33. An algorithm for optimizing a roller-cone bit, comprising the actions of:

reading the initial information on

the bit to be optimized,  
the formation to be drilled, and  
the operational parameters;

defining the optimization objectives based on the bit size and type;

simulating the operation of the drill bit having the operational design parameters through the formation to be drilled;

outputting

the forces on the teeth, cones, and bit;  
bit-balanced conditions; and  
bottom hole pattern;

defining design variables and their bounds;

generating linear and nonlinear constraints on the design variables;

calling a simplified two-dimensional bit/formation interaction model;

scaling said two-dimensional results using the initial three-dimensional results;

determining optimized bit parameters using said scaled results; and  
redesigning said bit using the optimized bit parameters.

34. The algorithm of Claim 33, wherein said linear constraints include the upper and lower bounds of a tooth crest length.

35. The algorithm of Claim 33, wherein said linear constraints include the upper and lower bounds of an orientation angle.

36. The algorithm of Claim 33, wherein said nonlinear constraints include the clearance between teeth surfaces on all cones.
37. The algorithm of Claim 33, wherein said nonlinear constraints include the width of the uncut formation rings on the bottom of the formation to be drilled.
38. A roller cone bit designed by the algorithm of Claim 33.
39. A method of drilling using bits designed by the algorithm of Claim 33.